CHAPTER SIXTEEN

Metal Oxide Semiconductor Field Effect Transistors [MOSFET]

Digital Electronics.

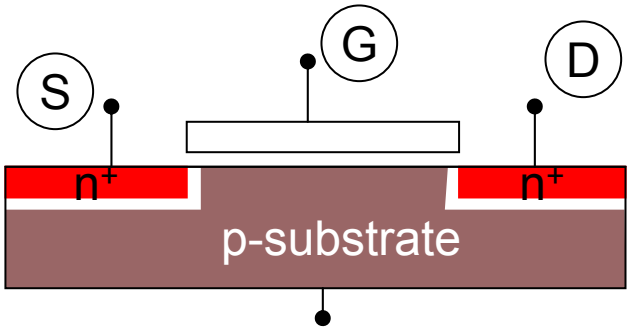
Introduction

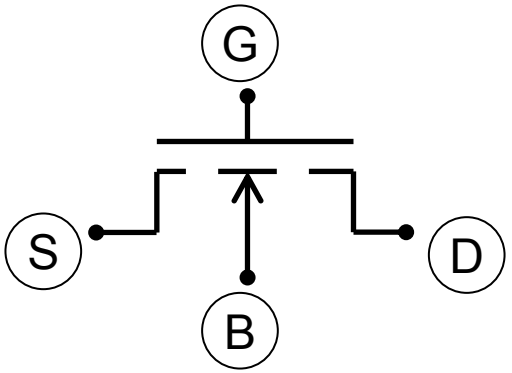
MOSFET transistors have smaller size than BJT transistors

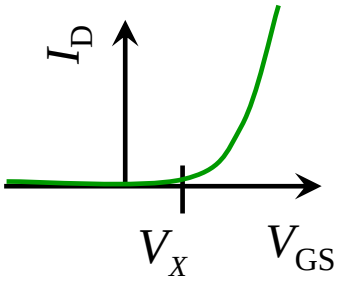
MOSFET transistors have lower power consumption than that of BJT transistors

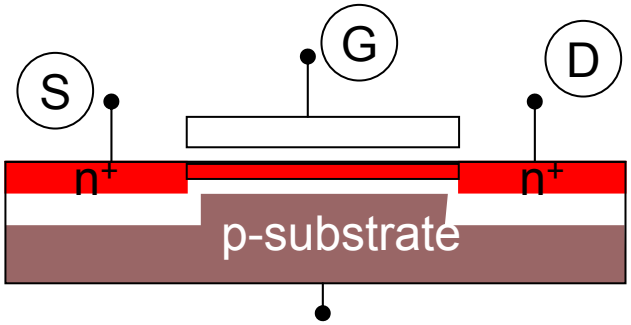
Types of MOSFETs

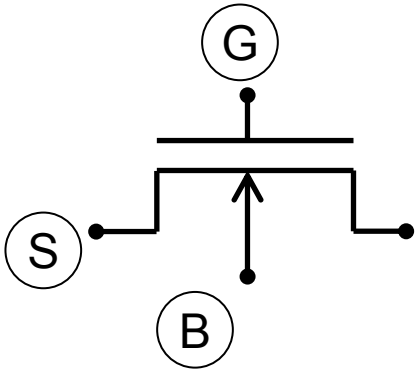
√ *faster (mobility of electrons is higher than of holes)*

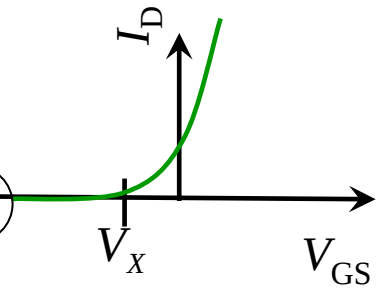




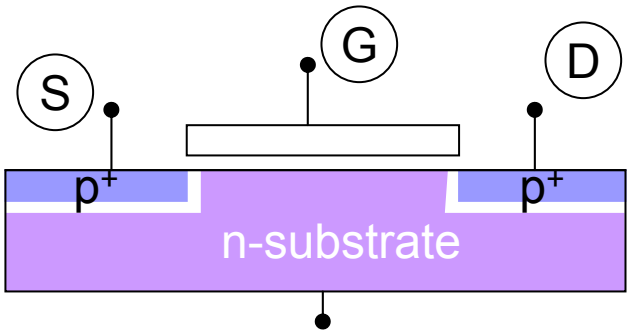


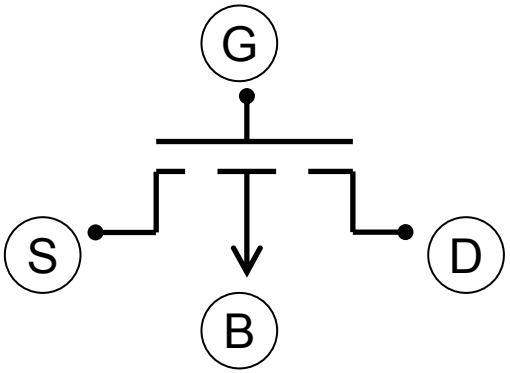


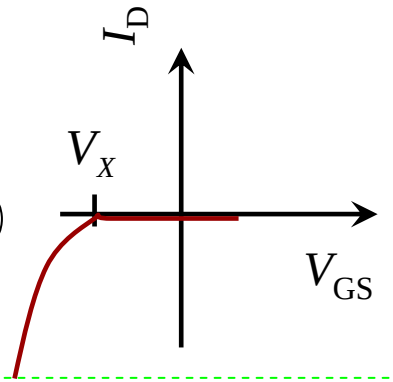


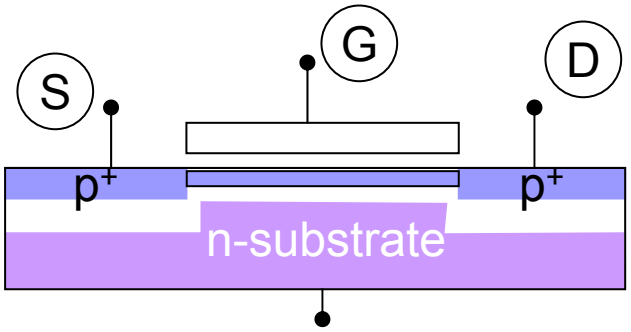


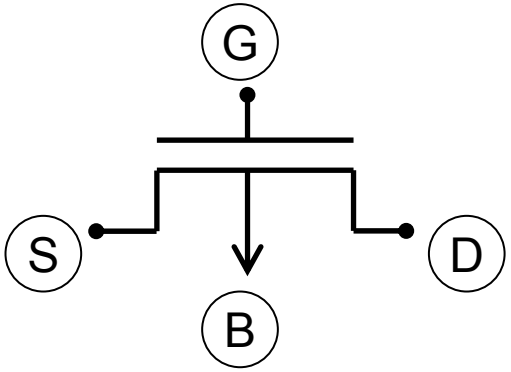
Types of MOSFETs

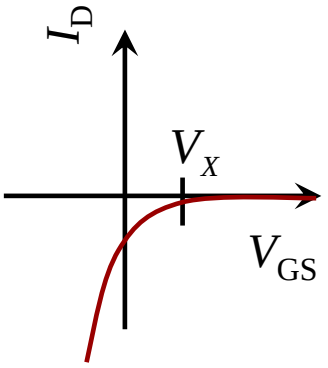




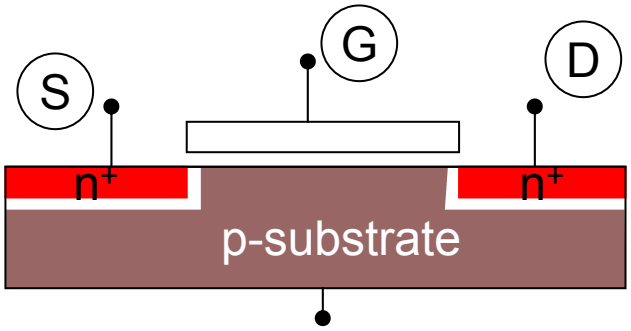


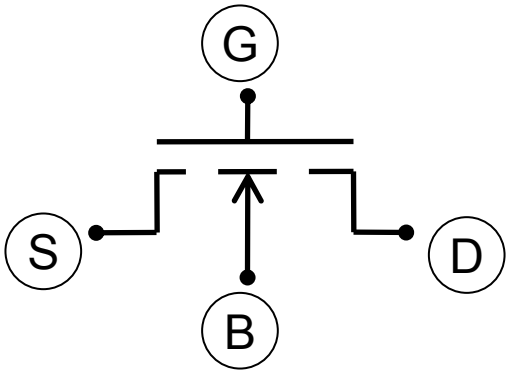






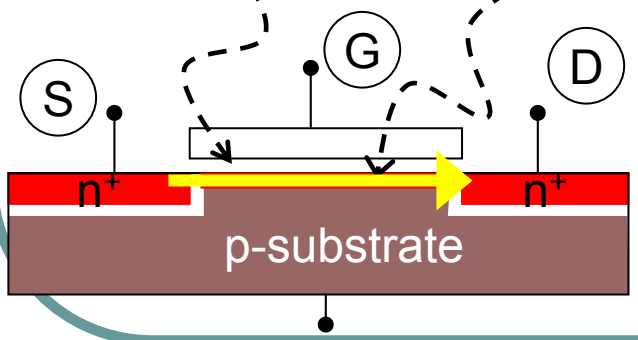
N- MOSFET





The Drain-to-Source current (electrons are emitted from the source to the drain) $I_{DS} > 0$

$$V_{GS} > V_{TN} \quad \& \quad V_D > V_S$$



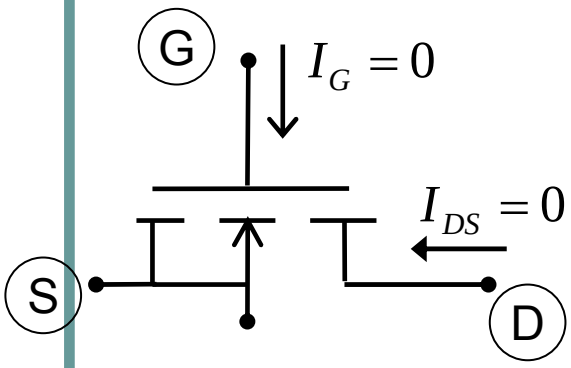
V_{TN} is the threshold voltage and defined as the minimum V_{GS} needed to create a channel between the source and the drain

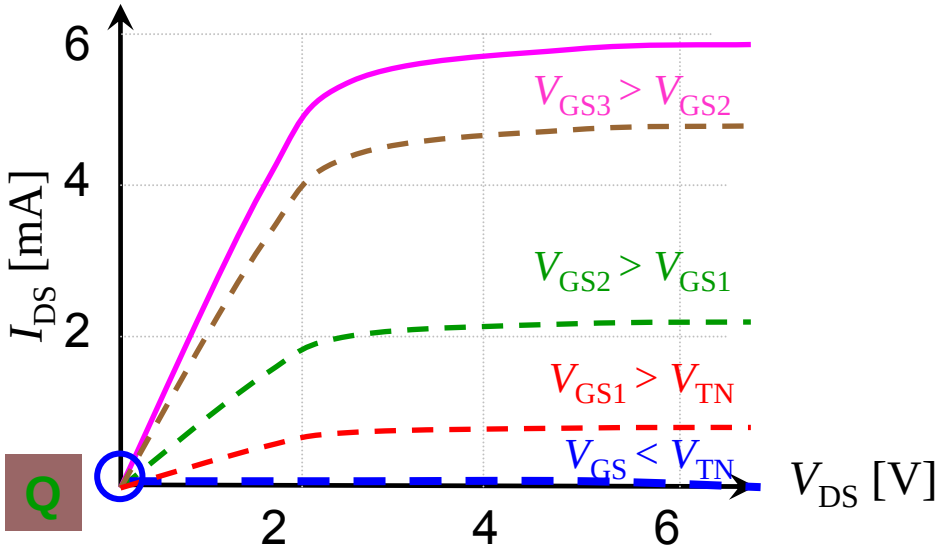
N- MOSFET (Modes of Operation)

There are three modes of operation of N-channel MOSFET (assuming the substrate and the source are connected)

1 Mode Cut-Off

$(V_{GS} < V_{TN})$





$I_{DS} = 0$

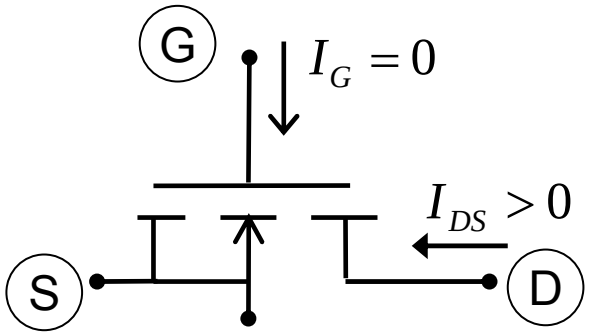
N- MOSFET (Modes of Operation)

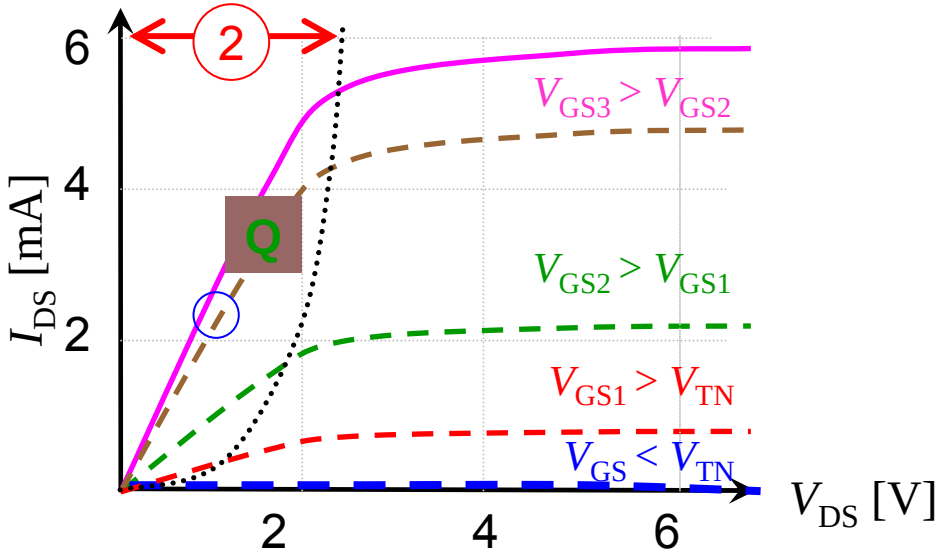
There are three modes of operation of N-channel MOSFET (assuming the substrate and the source are connected)

2 Linear Mode

$$(V_{GS} \geq V_{TN})$$

$$V_{DS} \leq V_{GS} - V_{TN}$$





$$I_{DS} = \frac{K_n}{2}\left[2 \times (V_{GS} - V_{TN})V_{DS} - V_{DS}^2\right]$$

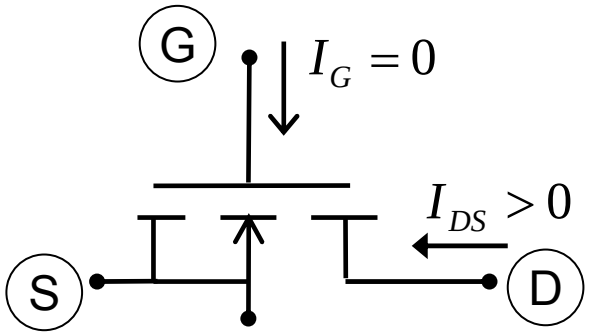
N- MOSFET (Modes of Operation)

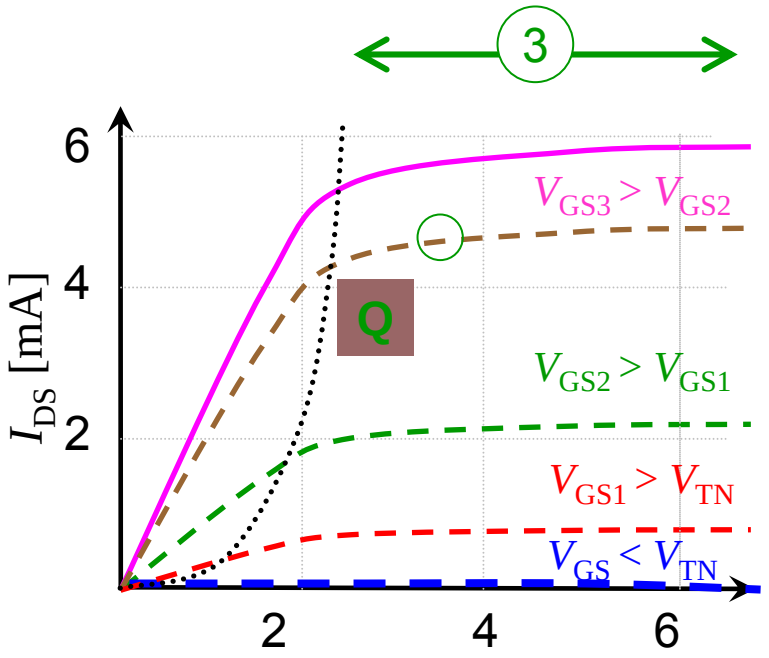
There are three modes of operation of N-channel MOSFET (assuming the substrate and the source are connected)

3 Saturation Mode

$$(V_{GS} \geq V_{TN})$$

$$V_{DS} \geq V_{GS} - V_{TN}$$





$$I_{DS} = \frac{K_n}{2}(V_{GS} - V_{TN})^2$$

$$I_{DS} = \frac{K_n}{2}(V_{GS} - V_{TN})^2(1 + \lambda V_{DS})$$

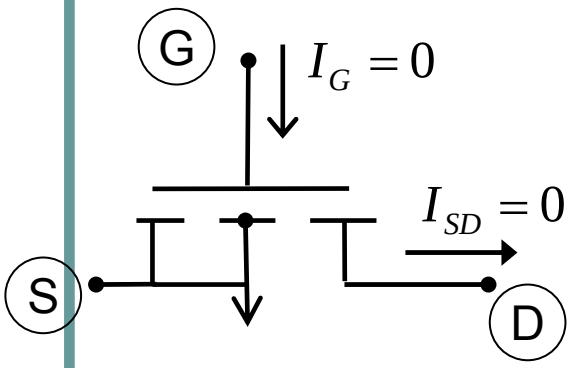
: *channel-length modulation parameter*

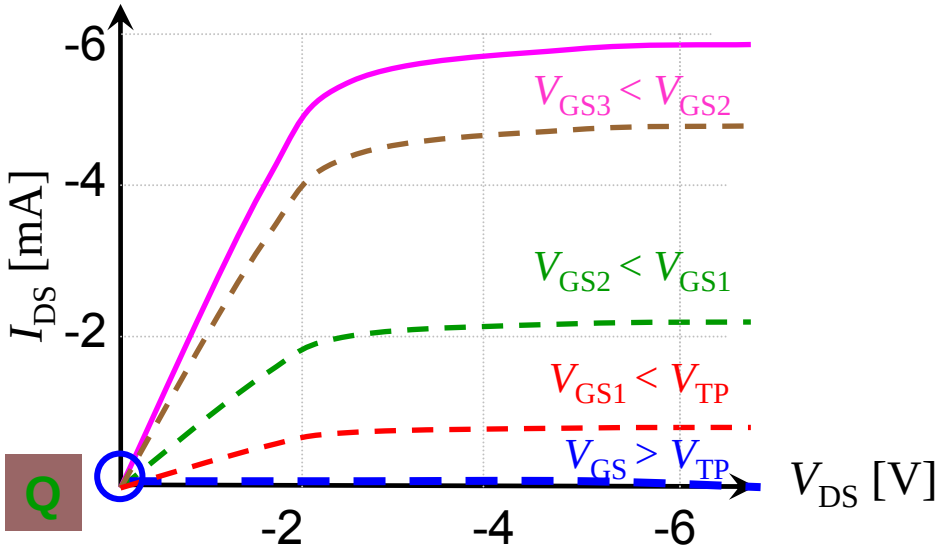
N- MOSFET (Modes of Operation)

There are three modes of operation of P-channel MOSFET (assuming the substrate and the source are connected)

1 Mode Cut-Off

$(V_{GS} > V_{TP})$ V_{TP} (−)





$I_{SD} = 0$

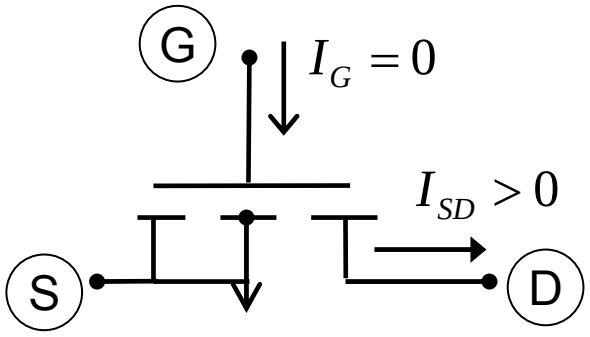
P- MOSFET (Modes of Operation)

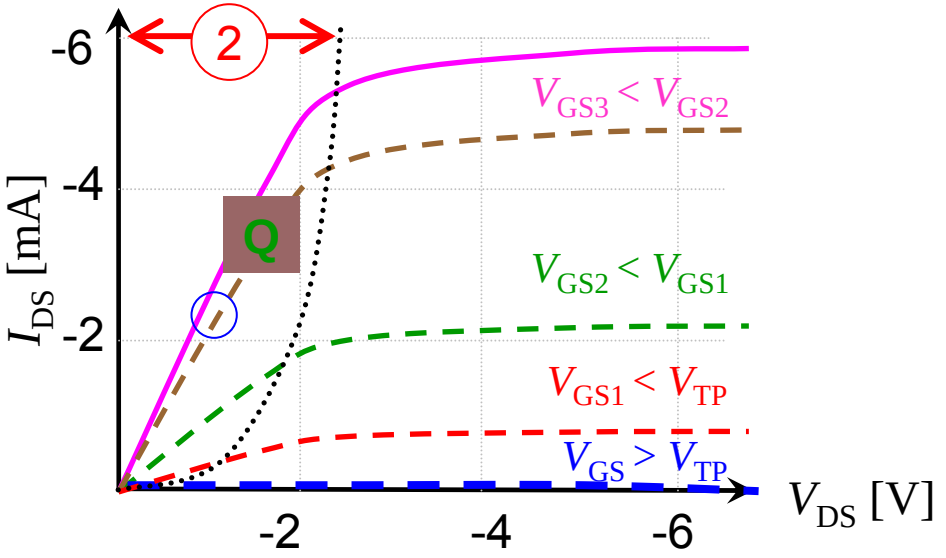
There are three modes of operation of P-channel MOSFET (assuming the substrate and the source are connected)

2 Linear Mode

$$(V_{GS} \le V_{TP})$$

$$V_{DS} \ge V_{GS} - V_{TP}$$





$$I_{SD} = \frac{K_p}{2}\left[2 \times (V_{GS} - V_{TP})V_{DS} - V_{DS}^2\right] \quad \text{OR} \quad I_{SD} = \frac{K_p}{2}\left[2 \times (V_{SG} + V_{TP})V_{SD} - V_{SD}^2\right]$$

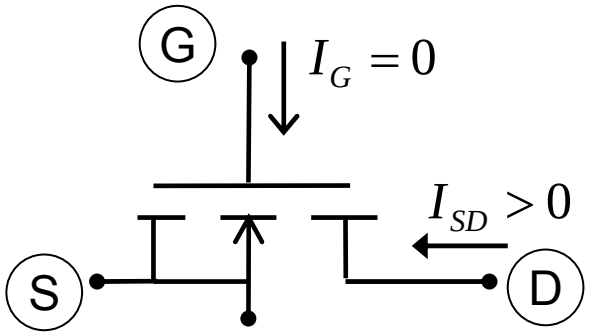
P- MOSFET (Modes of Operation)

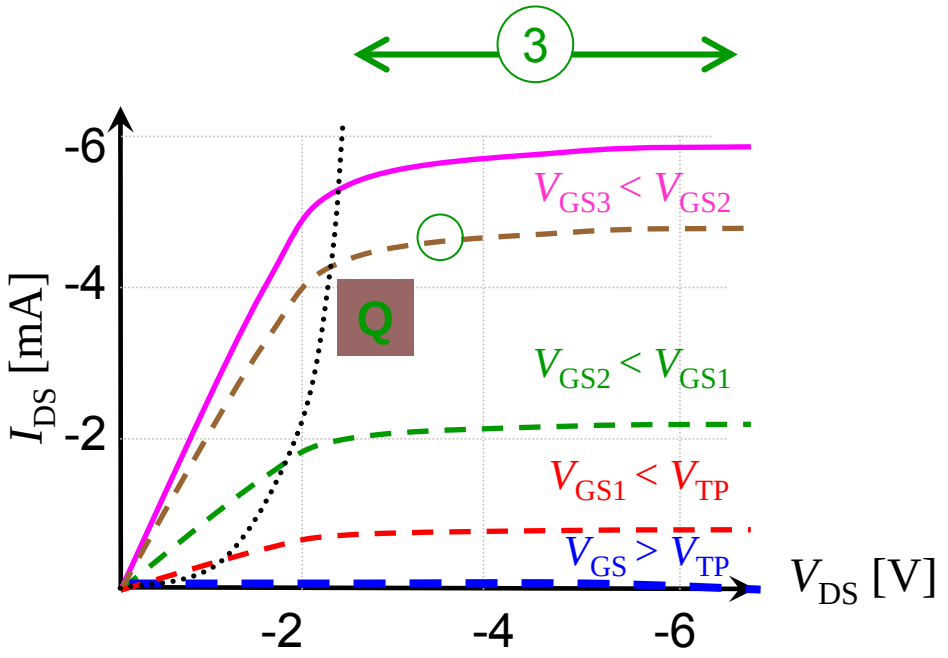
There are three modes of operation of P-channel MOSFET (assuming the substrate and the source are connected)

3 Saturation Mode

$$(V_{GS} < V_{TP})$$

$$V_{DS} \leq V_{GS} - V_{TP}$$





$$I_{SD} = \frac{K_P}{2}(V_{GS} - V_{TP})^2 \quad \text{OR} \quad I_{SD} = \frac{K_P}{2}(V_{SG} + V_{TP})^2$$

Example

Determine the drain current of an NMOS transistor assuming $K_n = 20\mu A/V^2$, $V_{TN} = 1V$, $\lambda = 0$, and $V_{GS} = 3V$

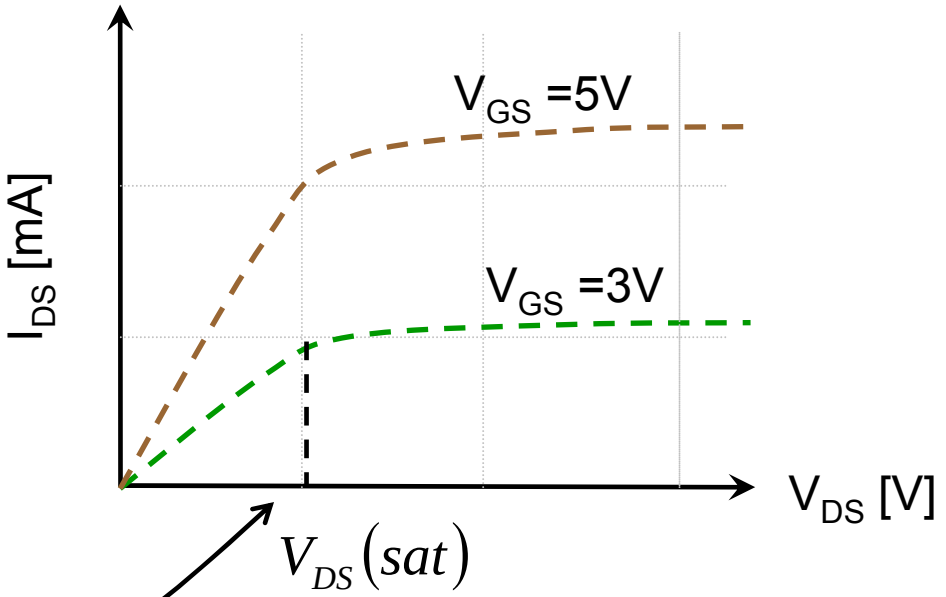
Solution

$$I_{DS}(sat) = \frac{K_n}{2}(V_{GS} - V_{TN})^2(1 + \lambda V_{DS})$$

$$I_{DS}(sat) = \frac{20 \times 10^{-6}}{2}(3-1)^2(1 + 0 \times V_{DS})$$

$$I_{DS}(sat) = 40\mu A$$

$$V_{DS}(sat) = V_{GS} - V_{TN} = 2V$$



Skip the MOSFET capacitances (sec. 6.7) and the fabrication processes of MOSFET devices